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An Investigation of the Role of Current and Future Remote Sensing Data Systems in Numerical Meteorology

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I. Background

The goals of this research endeavor have been to develop a flexible and relatively complete framework for the investigation of current and future satellite data sources in numerical meteorology. In order to realistically model how satellite information might be used for these purposes, it is necessary that Observing System Simulation Experiments (OSSEs) be as complete as possible. It is therefore desirable that these experiments simulate in entirety the sequence of steps involved in bringing satellite information from the radiance level through product retrieval to a realistic analysis and forecast sequence. In this project we have worked to make this sequence realistic by synthesizing raw satellite data from surrogate atmospheres, deriving satellite products from these data and subsequently producing analyses and forecasts using the retrieved products.

II. Accomplishments in 1991

The emphasis in 1991 has been on examining atmospheric soundings and microphysical products which we expect to produce with the launch of the Advanced Microwave Sounding Unit (AMSU), slated for flight in mid 1994. We have accomplished several OSSEs in the past year for a mesoscale forecast environment in which we have examined the impact of the atmospheric soundings of temperature and water vapor which will be produced from this instrument, in combination with its companion infrared sounder, the HIRS. The OSSEs have all produced very similar results showing that in this sort of forecast environment the impact of the AMSU on the prediction of atmospheric temperature will be small but positive. More impact has been noted, however, in the prediction of fields of water vapor. This is not unexpected, since the AMSU will include new water-vapor-sensitive microwave channels, which have some capability for sounding through non-precipitating clouds. Future plans involve a closer examination of situations where the AMSU has advantages over the current HIRS-MSU instrument suite, cases where there are large areas of non-precipitating cloud.

The large frequency range of the suite of microwave channels which comprise the AMSU instrument means a range of sensitivities to the presence of cloud liquid water and other atmospheric microphysical parameters, which may be useful in the retrieval of these quantities from AMSU radiances. Cloud liquid water (CLW) is a fundamental quantity in the transfer of solar, microwave and infrared radiation in the atmosphere and work in the past year has concentrated on methods for retrieving this quantity from the AMSU and applying it to various facets of atmospheric modelling. Last year we reported on the development of a "Microwave Slicing" algorithm for the retrieval of the height and "effective" fraction of cloud appropriate for microwave radiation and also the first results of retrievals of total-column CLW amounts from the AMSU. The retrieval method was a non-linear maximum-likelihood type algorithm which simultaneously derives infrared and microwave cloud parameters as well as atmospheric soundings, developed by John Eyre (current affiliation, ECMWF) while he was a visiting scientist at the CIMSS. In the past year we have gained considerable experience in retrieving CLW from the AMSU and have run several experiments involving the retrieval of CLW using the CIMSS mesoscale model to produce realistic cloud water features. The "Microwave Slicing" algorithm has been incorporated as a preprocessing step in the full simultaneous non-linear retrieval algorithm to improve the character of the "first guess" of CLW for the full retrieval methodology. Results of the retrieval of cloud liquid water will be presented at the review meeting.

In order to more effectively examine the retrieval and modeling of CLW and other microphysical parameters, we have been steadily increasing the sophistication of the microphysical parameterizations in the CIMSS Mesoscale Model (the Subsynoptic-Scale Model, SSM). Cloud liquid water and an elementary ice form were added to the model based on similar parameterizations used in the Limited Area Mesoscale Prediction System (LAMPS), which is used by our MSFC colleagues. This system has proven to be remarkably accurate in the prediction of the location of cloud water and several examples will be shown at the review meeting of these predictions compared to satellite images and also in a "VIS-5D" (four dimensional display) environment. During the NOAA Stormfest experiment of early 1992, we ran the SSM in real time and gained much experience on the character of the microphysical predictions. We are continuing to run the model daily in real time to increase this experience base. We are also looking at increasing the complexity of the basic microphysics of the model to include a more complete treatment of ice and better representation of convective cloud and ice water. We have coupled the explicit microphysics in the model into its solar and infrared radiative transfer parameterization and the resulting radiation fields show definition and structure not present in the previously employed more basic scheme.

We are currently examining the coupling of retrieved CLW amounts into the initialization of short and medium-range forecast models. In the "explicit " cloud and rain water physics coming into use in forecast models, cloud water is a "reservoir" which must be filled to a critical value before precipitation can occur. In addition to the general "spin-up" problem inherent in these models, the time required to generate cloud water to the precipitation threshold may be detrimental to short-term precipitation forecasting. We are finding that cloud water initialization is of some help in reducing this spin-up if the model water vapor field is also modified in a consistent fashion. In the past year, we have also done some investigation of the initialization of latent heating fields in the model (presumably from satellite or surface-measured rainfall rates) within the framework of the model "vertical mode initialization" scheme, which has also helped in reducing spin-up effects.

III. Focus of Current and Future Research

The goals current and future research in the coming year are:

1. Continue to improve the microphysical parameterizations in the SSM so that OSSEs can be made more realistic and comprehensive. This will include better representations of ice phases and improved parameterizations for water and ice phases from convective processes.
2. Examine in more detail the cloud liquid water information available from the AMSU and whether the suite of channels on the satellite platform will provide any profile information on this quantity. Two complementary methods will be investigated and these will be discussed at the review meeting.
3. Examine cloudy situations and the potential improvement of atmospheric soundings provided over current systems by the AMSU. Continue to evaluate cloud water and latent heating initialization in short and medium-range forecasts.

IV. Recent Publications

Huang, H. L. and G. R. Diak, 1992: Retrieval of nonprecipitating liquid water cloud parameters from microwave data: a simulation study. J. Atmos. Ocean. Tech., June issue.

Diak, G. R., D. Kim, M. A. Whipple and X. H. Wu: Preparing for the AMSU. Bull. Am. Meteor. Soc., In review.

Huang. H. L. and G. R Diak, 1992: Estimation of liquid water cloud height and fraction using simulated AMSU-A and MHS data. Preprint volume, AMS Sixth Conference on Satellite Meteorology and Oceanography, Atlanta, GA, Jan. 5-10, 1992, 219-222.

Huang, H. L., W. L. Smith, G. R. Diak and H. M. Woolf, 1991: Future hybrid infrared and microwave satellite system- A theoretical analysis of its capability. AMS Seventh Conf. on Meteorological Observations and Instrumentation, New Orleans, LA, Jan. 14-18, 428-430.

Diak, G. R., H. L. Huang and D. Kim, 1990: Observing system simulations using synthetic radiances and atmospheric retrievals derived for the AMSU and HIRS in a mesoscale model. AMS Fifth Conf. on Satellite Meteorology and Oceanography, London, England, Sept. 3-7, 1990.